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## IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of: John Mak, Richard Nielsen, Thomas King Chow, Oliver Morgan, and Vincent Wai Wong

For: Methods and Configurations for Acid Gas Enrichment and Sulfur Recovery

Mail Stop Provisional Patent Application  
Commissioner for Patents  
P.O. Box 1450  
Alexandria, VA 22313-1450

COVER SHEET FOR FILING PROVISIONAL APPLICATION  
(37 C.F.R. § 1.51(c)(1))

This is a request for filing a PROVISIONAL APPLICATION FOR PATENT under 37 C.F.R. § 1.51(c)(1)(i). The following comprises the information required by 37 C.F.R. § 1.51(c)(1):

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1. The following comprises the information required by 37 C.F.R. § 1.51(c)(1):
2. The names and residence address of the inventors are (37 C.F.R. § 1.51(c)(1)(ii)):

1. John Mak – Santa Ana, CA
2. Richard Nielsen – Laguna Niguel, CA
3. Thomas King Chow – Villa Park, CA
4. Oliver Morgan - Huntington Beach, CA
5. Vincent Wai Wong - Hacienda Heights, CA

3. The title of the invention is (37 C.F.R. § 1.51(c)(1)(iv)):

Further Methods and Configurations for Acid Gas Enrichment and Sulfur Recovery

4. The name, registration, customer and telephone numbers of the practitioner are (37 C.F.R. § 1.51(c)(1)(v)):

Name of practitioner: Martin Fessenmaier  
Reg. No. 46697  
Tel. 714-641-5100  
Customer No. 34284

5. The docket number used to identify this application is (37 C.F.R. § 1.51(c)(1)(vi)):

Docket No. 100325.0246PRO

6. The correspondence address for this application is (37 C.F.R. § 1.51(c)(1)(vii)):

Rutan & Tucker, LLP  
611 Anton Blvd., Suite 1400  
Costa Mesa, CA 92626  
USA

7. Statement as to whether invention was made by an agency of the U.S. Government or under contract with an agency of the U.S. Government. (37 C.F.R. § 1.51(c)(1)(viii)).

This invention was NOT made by an agency of the United States Government, or under contract with an agency of the United States Government.

8. Identification of documents accompanying this cover sheet:

A. Documents required by 37 C.F.R. § 1.51(c)(2)-(3):

Specification:	No. of pages	<u>7</u>
Drawings:	No. of sheets	<u>5</u>

9. Fee

The filing fee for this provisional application, as set in 37 C.F.R. § 1.16(k), is \$160.00 for other than a small entity.

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Fee payment in the amount of \$160.00 is being made at this time.

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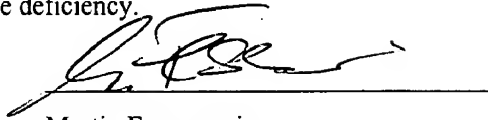
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Martin Fessenmaier  
Registration No. 46697  
Rutan & Tucker, LLP  
611 Anton Blvd., Suite 1400  
Costa Mesa, CA 92626  
USA  
714-641-5100  
Customer No. 34284

## **FURTHER METHODS AND CONFIGURATIONS FOR ACID GAS ENRICHMENT AND SULFUR RECOVERY**

### **Field of The Invention**

5           The field of the invention is gas processing and sulfur removal, especially as it relates to enrichment of an acid gas stream and tail gas treating from Claus plant.

### **Background of The Invention**

10           There are numerous sources of natural or synthesis gas known in the art, and almost all of them contain H<sub>2</sub>S in various quantities that require at least partial desulfuration prior to further processing or release into the atmosphere. For example, natural gas, refinery gas, synthesis gas (e.g., from gasification of residual oil or coke), or Fischer-Tropsch gas-to-liquids process (GTL) gases often contain H<sub>2</sub>S in significant amounts that would interfere with downstream processes. Furthermore, the sulfur content in the tail gas from the Claus reactors typically requires treatment before releasing the tail gas to the environment.

15           If H<sub>2</sub>S is present in large quantities, removal is commonly accomplished by absorption in an alkaline solvent, usually with an amine solvent. H<sub>2</sub>S is later regenerated or desorbed in a regenerator in a stripper operating at a lower pressure and elevated temperature. The acid gas from the regenerator is then typically processed in a Claus plant where the H<sub>2</sub>S is converted to elemental sulfur by sub-stoichiometric reaction with air or oxygen.

20           However, nearly all gas streams which contain H<sub>2</sub>S also contain significant quantity of CO<sub>2</sub> and when such gases are simply scrubbed with an alkaline solution, CO<sub>2</sub> is co-absorbed with the H<sub>2</sub>S. This is particularly problematic where the ratio of CO<sub>2</sub> to H<sub>2</sub>S in the gas stream is relatively high, as complete removal of both gases will often produce an acid gas weak in H<sub>2</sub>S, which tends to cause various problems in the Claus plant. Among other things, the dilution effect  
25           of CO<sub>2</sub> in such acid gases lowers the net heating value in the acid gas and also reduces the residence time in the Claus furnace, rendering sulfur conversion difficult. Moreover, such acid gases also contain significant quantities of contaminants (e.g., benzene, toluene, xylene) that generally must be destroyed in the Claus furnace, which is necessary for protection of the Claus

reactor catalysts. Unfortunately, the CO<sub>2</sub> dilution effect in such acid gases tends to lower the furnace flame temperature, thereby making destruction of these contaminants difficult.

In extreme cases, where the H<sub>2</sub>S content in the acid gas falls below 10%, a normal Claus reaction becomes impossible and additional processing steps must be employed to enhance the conversion process. Additionally, the dilution effect of CO<sub>2</sub> will increase the size of the Claus plant as the plant size is predominantly controlled by the total volumetric flow of acid gas.

Where the acid gas is unsuitable as feed to a Claus plant, preprocessing using a selective acid gas removal process is frequently necessary. In a typical preprocessing operation, two gas streams are produced via selective absorption of H<sub>2</sub>S from the acid gas and subsequent stripping of the rich solvent. Thus, one gas stream predominantly comprises CO<sub>2</sub> that can be sent to a thermal oxidizer or incinerator for conversion of residual H<sub>2</sub>S to SO<sub>2</sub>, prior to being discharged to the atmosphere via a stack. The other gas stream is typically enriched in H<sub>2</sub>S and is then processed in a simple Claus plant.

Generation of a sweet CO<sub>2</sub> stream can be particularly advantageous. Unlike the tail gas stream from a Claus plant, a sweet CO<sub>2</sub> stream is essentially free of nitrogen and can be further compressed and utilized for enhanced oil recovery, or as a diluent for controlling the flame temperature (NO<sub>x</sub> control) in a gas turbine of an IGCC. Another advantage of selective gas treating is in the processing of Claus plant tail gas to meet environmental requirements. A typical Claus plant can recover about 95% of the sulfur contents in an acid gas stream. The residual sulfur content can later be removed and recovered in a tail gas unit, with the regenerated H<sub>2</sub>S (via regeneration of the rich solvent) recycled back to Claus unit.

Known processes for selective H<sub>2</sub>S removal from high CO<sub>2</sub> gases include the Stretford process, LOCAT and Sulferox unit. These processes employ complex catalyst-based chemistry to oxidize H<sub>2</sub>S directly to sulfur. However, these units are often complex, difficult to operate, and are limited to relatively small capacity. Alternatively, various known amine based solvents capable of selectively removing H<sub>2</sub>S can be used. For example, selective absorption processes can be based on blended tertiary amines (*e.g.*, those comprising diisopropanolamine (DIPA), formulated methyldiethanolamine (MDEA), and other amine-organic solvent blends). Such

solvents, particularly when combined with specially adapted absorber internal designs will minimize co-absorption of CO<sub>2</sub> (typically, such processes can concentrate the H<sub>2</sub>S content by a factor of three to five fold). Other processes for selective H<sub>2</sub>S removal include the use of sterically hindered tertiary amino compounds described in U.S. Pat. Nos. 4,405,580.

5 In still further attempts to increase selectivity of absorption, special tray configurations can be employed to reduce the contact time with CO<sub>2</sub> to achieve the required selectivity. For example, U.S. Pat. Nos. 4,278,621 and 4,297,329 and 4,678,648 describe special tray and packing designs in minimizing CO<sub>2</sub> contact time. Unfortunately, the use of such processes and/or devices provide in most cases only marginal benefit for treating a diluted acid gas stream.

10 Alternatively, as described in U.S. Pat. Nos. 4,198,386 and 4,093,701, selectivity is achieved by varying gas flow-rates using a plurality of absorption columns, and splitting the absorber column into a number of absorption zones with controlled flow-rates of lean amine solvent. However, such systems typically require additional pipes and valves, and are often costly and complicated to operate. In yet further attempts to increase selectivity, H<sub>2</sub>S absorption may be  
15 enhanced via temperature control. Generally, a reduction in absorption temperature slows the CO<sub>2</sub> absorption rate. However, the cost of operating a refrigeration unit render such an option often uneconomical.

Even where selective acid gas absorption is practiced with concurrent conversion of H<sub>2</sub>S to elemental sulfur in Claus plant, the residual sulfur content in Claus plant tail gases frequently  
20 poses additional problems. Among other things, the Claus plant tail gas often contains substantial quantities of H<sub>2</sub>S and therefore fails to qualify for emission standards that would allow such tail gas to be vented into the atmosphere. Numerous configurations are known in the art to reduce the sulfur content of such tail gas. However, most of such configurations are relatively complex and expensive to build and/or operate.

25 Therefore, and especially where a diluted acid gas feed is employed, currently known methods and configurations are often neither suitable nor economical. Thus, there is still a need to provide improved configurations and methods for selective acid gas enrichment.



### **Detailed Description**

The inventors generally contemplate integrated configurations and methods of selective H<sub>2</sub>S absorption and sulfur recovery from various gases comprising H<sub>2</sub>S and CO<sub>2</sub>, and especially from gases in which H<sub>2</sub>S is diluted.

5           In one aspect, and with respect to selective H<sub>2</sub>S absorption, contemplated configurations employ an amine solvent (*e.g.*, methyldiethanolamine based solvent for preferential H<sub>2</sub>S absorption), and a dilute acid gas is first contacted with the lean solvent for selective removal of H<sub>2</sub>S, thereby producing (1) an overhead CO<sub>2</sub> vapor with ppm level of H<sub>2</sub>S suitable for disposal in an incinerator, and (2) a H<sub>2</sub>S rich solvent that is processed in a regenerator. The regenerator  
10           produces a H<sub>2</sub>S enriched acid gas, a portion of which is contacted by a second amine contactor, producing an overhead CO<sub>2</sub> vapor with ppm level of H<sub>2</sub>S suitable for disposal in an incinerator, and a H<sub>2</sub>S rich solvent that is recycled to the regenerator.

          In an especially preferred aspect, the acid gas enrichment process is integrated with a Claus plant and a catalytic hydrogenation reactor, wherein the H<sub>2</sub>S enriched acid gas from the  
15           selective absorption process is sent to the integrated Claus unit. With respect to configurations and methods for selective H<sub>2</sub>S absorption from an acid gas comprising CO<sub>2</sub>, the same considerations as described in our copending U.S. provisional patent application with the title "Methods and Configurations for Acid Gas Enrichment" (filed on or about 01/20/2004 (John Mak et al.), and incorporated by reference herein) apply.

20           In particularly contemplated integrated configurations, the tail gas from the Claus plant is passed through a catalytic hydrogenation reactor and a quench column forming a tail gas containing a dilute concentration of H<sub>2</sub>S. The tail gas is treated in a third absorber, using lean solvent produced from the regenerator, producing an overhead CO<sub>2</sub> vapor with ppm level H<sub>2</sub>S suitable for incinerator, and a H<sub>2</sub>S rich solvent that is recycled to the regenerator. Thus, it should  
25           be recognized that contemplated configurations lower the overall treating and sulfur recovery costs while minimizing emission problems. Based on various calculations, the inventors discovered that sulfur can be recovered up to 99.7% (and even higher) with significantly reduced capital and operating costs as compared to heretofore known configurations. Therefore, viewed

from another perspective, the inventors contemplate a two amine absorption stage enrichment process that enriches H<sub>2</sub>S in diluted acid gas to about 75%. It should be especially recognized that such process can be used with various solvents and associated equipment, including formulated MDEA (from Dow or INEOS) or from ExxonMobil's Flexsorb process.

5        **Figure 1** shows an exemplary integrated configuration according to the inventive subject matter. The inventors discovered that combinations of an enrichment unit and a third absorber processing the tail gas from the Claus unit can effectively achieve a 99.7% or higher sulfur recovery with significantly reduced equipment.

Here, a two-stage Claus reactor system is used to process the enriched acid gas stream 18.  
10    It should be appreciated that a conventional sulfur plant without a tail gas treatment option would typically require four-stage Claus reactors and additional processing steps in order to achieve 99% sulfur recovery. In contrast, contemplated integrated tail gas absorption configurations significantly reduce overall cost when compared to conventional plants. The effluent gas from the Claus unit (stream 30), typically comprising trace quantities of sulfur oxides and unconverted  
15    H<sub>2</sub>S, is processed in a hydrogenation unit 71. The hydrogenated gas is quenched, cooled and the resultant gas is scrubbed in the tail gas scrubber 72, producing stream 31. The lean amine (stream 32), at a flow rate of about 300 GPM is supplied from the lean amine header to the absorber. The tail gas absorber overhead vapor stream 33 comprising trace levels of H<sub>2</sub>S can be routed to incinerator for disposal.

20        The rich amine stream 34 from the third absorber is pumped by amine pump 73 to about 50 psig forming stream 35 which is then combined with the rich amine 7 from the first absorber 51, forming stream 36. The combined stream is heated in the lean/rich exchanger and fed to the common regenerator.

Alternatively, **Figure 2** shows another exemplary integrated configuration with a Claus  
25    unit. In this configuration, the semi-loaded solvent 32 from the tail gas absorber 72 is re-used in the second absorber 22 and fed to the lower section of the second absorber. This economizes the solvent circulation and regeneration duties. With this arrangement, the incremental amount of solvent used in the tail absorber can be reduced, making the system integration more economical.

**Figure 3** shows yet another exemplary integrated configuration with a Claus unit. This configuration is similar to **Figure 4** with the exception that a portion of the semi-loaded solvent 7 from the first absorber 71 is re-used as stream 74. This semi-loaded solvent is cooled in a cooler 73 to about 100°F forming stream 75. This cold semi-loaded solvent is routed to the lower  
5 section of the second absorber 52. This configuration further reduces the solvent circulation and regeneration duties, making the integration energy efficient requiring the least solvent circulation.

In still further preferred aspects of the inventive subject matter, it should be recognized that the acid gas stream from the regenerator can be split into a first and second stream to achieve even better H<sub>2</sub>S removal and/or improve cost effectiveness. Such configurations may include an  
10 integrated Claus plant as depicted in the exemplary configuration of **Figure 4**, or operate as acid gas removal plant without integrated Claus plant as depicted in the exemplary configuration of **Figure 5**.

With reference to **Figure 4** where the Claus plant is integrated into the acid gas removal plant, the acid gas stream 14 from the regenerator is split into two portions: Stream 14 and stream  
15 17. Stream 14 is fed to the bottom of absorber 72 (tail gas absorber). The hydrogenated tail gas stream 31 is fed from the Claus plant hydrogenator to the mid section of the absorber 72. It should be recognized that such split flow configuration takes advantage of the amine used to clean up the tail gas (stream 31) for further absorption in the lower section of the absorber 72. Alternatively, stream 31 and stream 17 can be combined and fed to the bottom of the absorber  
20 72. Consequently, it should be appreciated that such configurations have eliminated the requirement of previously required absorber 52, resulting in significant cost savings.

Similarly, without integrated Claus plant as shown in **Figure 5**, the acid gas stream 17 in the split-flow configuration is divided into two streams, stream 90 and 91. Stream 91 can be combined with feed gas stream 1 forming stream 92. Recycling at least a portion of the acid gas  
25 stream to the feed gas is particularly advantageous to further enhance the H<sub>2</sub>S content in the enriched gas stream. Moreover, it should be recognized that such configurations may be especially useful where the flow of feed gas is variable with varying H<sub>2</sub>S content.

Thus, it should be particularly appreciated that configurations according to the inventive subject matter will produce an acid gas enriched in H<sub>2</sub>S from a lean H<sub>2</sub>S stream, wherein the acid gas can be enriched from about 7% to about 75% H<sub>2</sub>S. Moreover, preferred configurations allow removal of hydrocarbons and BTEX components that is problematic with sulfur plant operation. Still further, it should be recognized that contemplated configurations will produce a CO<sub>2</sub> stream with low H<sub>2</sub>S content suitable for disposal in incinerators. Alternatively, the CO<sub>2</sub> stream may also be employed for enhanced oil recovery or as a diluent in a gas turbine.

In present integrated Claus plant configurations, two otherwise necessary stages of Claus reactors can be eliminated, which substantially reduces overall plant cost. Still further, contemplated configurations solve the problems of low H<sub>2</sub>S content and lower heating content in the acid gas where the acid gas is diluted. Therefore, difficulties associated with fuel gas firing for the Claus reaction and BTEX destruction are eliminated. It should be further recognized that contemplated configurations and processes may advantageously be employed with various gas plants, sulfur plants, Gas-to-Liquid conversion plants, gasification plant, IGCCs, enhanced oil recovery plants, and various existing facilities that are retrofitted to meet more stringent emission requirements.

Thus, specific embodiments and applications of acid gas enrichment and sulfur recovery have been disclosed. It should be apparent, however, to those skilled in the art that many more modifications besides those already described are possible without departing from the inventive concepts herein. The inventive subject matter, therefore, is not to be restricted except in the spirit of the present disclosure. Moreover, in interpreting the specification, all terms should be interpreted in the broadest possible manner consistent with the context. In particular, the terms "comprises" and "comprising" should be interpreted as referring to elements, components, or steps in a non-exclusive manner, indicating that the referenced elements, components, or steps may be present, or utilized, or combined with other elements, components, or steps that are not expressly referenced.

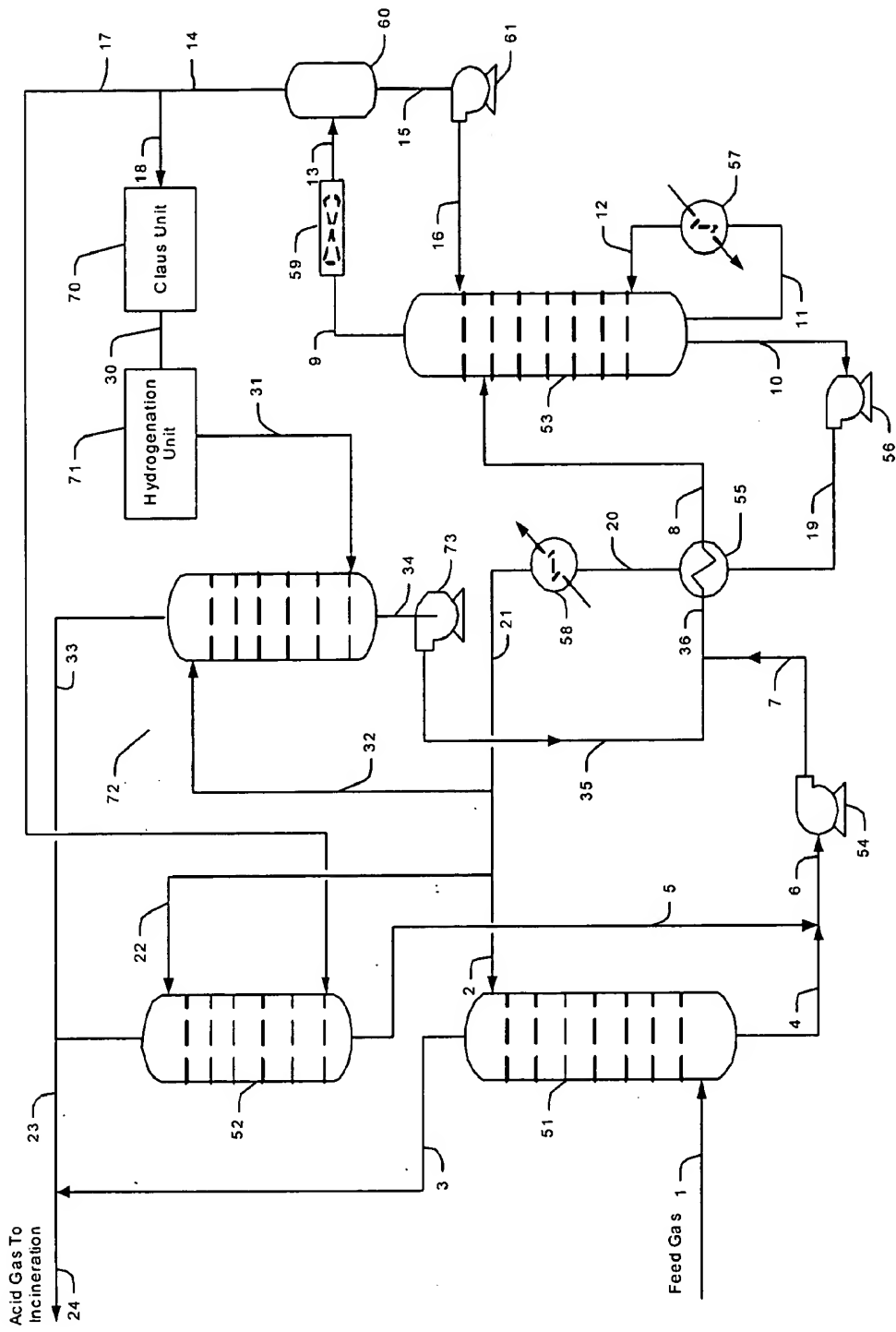


Figure 1



## Figure 2





### Figure 4



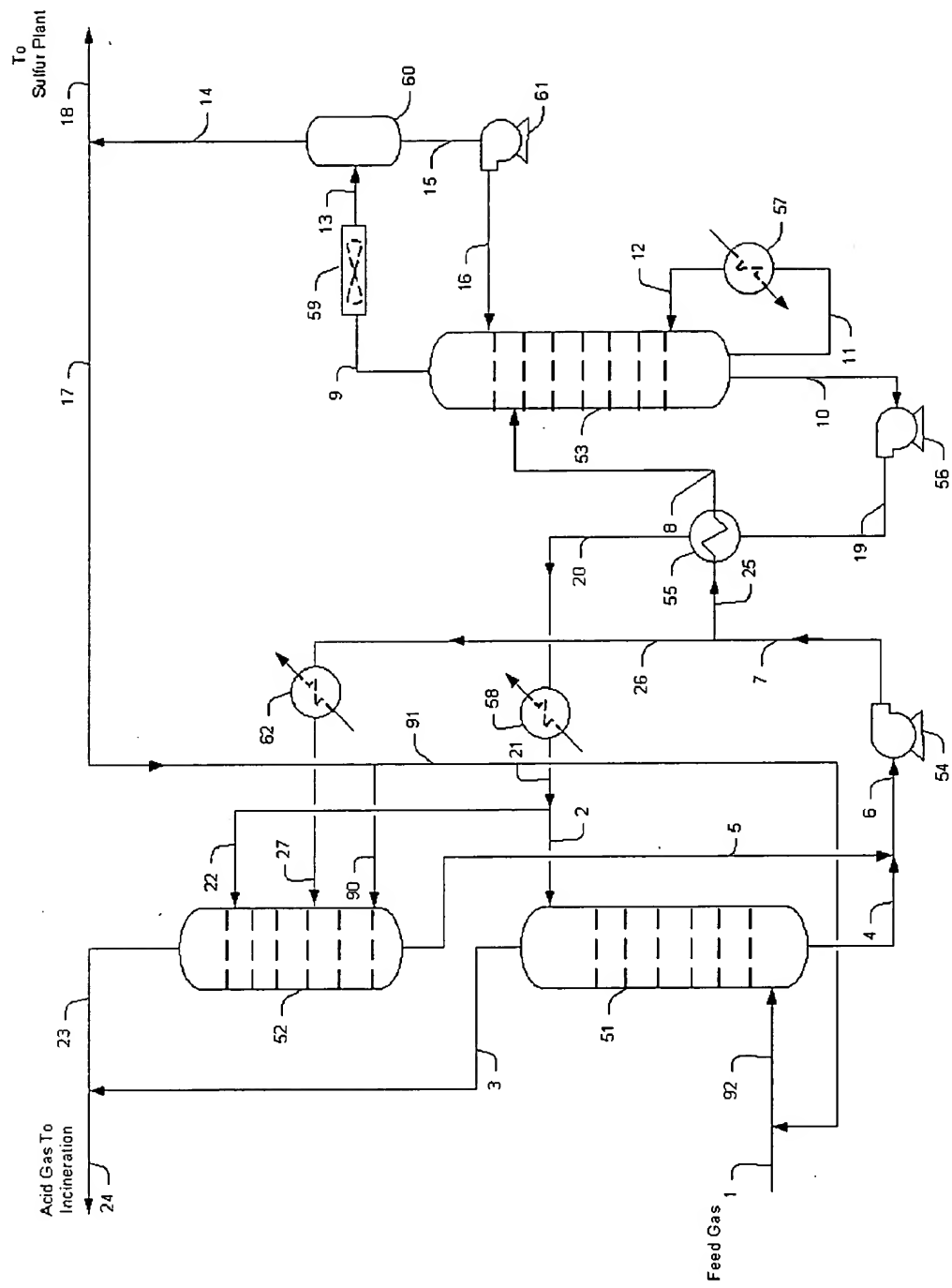


Figure 5